Information Relativity Theory (Part I): Time and Distance Transformations

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Abstract

Einstein's theory of special relativity (SR) theory dictates, as a *force majeure*, an ontic view, according to which relativity is a true state of nature. For example, the theory's solution to the famous twin paradox prescribes the "traveling" twin returns truly and verifiably younger than the "staying" twin, thereby implying the "traveling" twin returns to the future.

I propose an *epistemic* view of relativity, according to which relativity results from *difference in Information about Nature* between observers who are in motion relative to each other. The proposed theory, termed *Information Relativity* (*IR*) theory is based on two axioms: For the case of constant relative velocities, I derive the theory's time and distance transformations and compare them with the corresponding SR's transformations. I show that despite *IR*'s contradiction with Lorentz's Invariance Principle, it accounts as good as *SR* for the results of a class of time measurement experiments, including Michelson-Morley's type of experiments as well as the time dilation detected in muon decay and in "around-the-world atomic clocks" experiments. More important, the theory accounts for the linear Sagnac effect, which starkly disobeys *LI* and *SR*. It also predicts with precision the $v - c/c$ values reported in several neutrino velocity experiments, conducted by OPERA and other collaborations. I outline the necessary conditions for a stringent comparative test between *IR* and *SR*, and explain why the experimental designs of the linear Sagnac and the neutrino velocity experiments qualify as stringent tests of both theories.

Keywords: Relativity, Information, Time dilation, Ontic, Epistemic, Michelson-Morley, Muon decay, Sagnac Effect, neutrino velocity, OPERA.

1. Introduction and Propositions

A fundamental and still debated question about the nature of quantum mechanics is whether the wave function is a state of nature (ψ-ontic) or a state of knowledge about Nature (ψ-epistemic). The ontic view of quantum states has a long history in the interpretation of quantum mechanics. Schrödinger initially interpreted the quantum state as a tangible physical wave, and this view continues to be the one most physicists and philosophers of science adopt [e.g., 1-3]. The epistemic view, although less common than the ontic view, also has a long tradition and has recently gained more supporters [e.g., 4-7]. Fuchs [8] notes that Einstein was the first to unambiguously state why the quantum state should be viewed as information about reality and not as ontic, one-to-one correspondence with reality. Einstein's view about the incompleteness of quantum theory, most known from the famous EPR paper [9], has been expressed more vigilantly in his correspondence with Schrödinger and with other scientists. In a letter to P. S. Epstein, 10 November 1945, Einstein wrote: "I incline to the opinion that the wave function does not (completely) describe what is real, but only a (to us) empirically accessible maximal knowledge regarding that which really exists" (A. Einstein, [10], quoted in [11]).

Remarkably, a parallel question regarding the nature of Einstein's theories of relativity has never been seriously raised, at least not in theory. The neglect is most probably due to the fact that special and general relativity theories, dictate, as a *force majeure*, an ontic view of relativity. For example, the solutions to the twin paradox in both theories prescribe the "traveling" twin returns truly and verifiably younger than the "staying" twin, thereby implying the "traveling" twin returns to the future.

Because Einstein’s model of the universe has been hardly challenged, no one seems to have found any utility in challenging the ontic view of relativity. Nonetheless, one should be allowed to ask what would be the aftermath of adopting an epistemic view of relativity (R-epistemic) rather than the standard view of relativity as a state of nature (R-ontic). The epistemic approach the present paper takes could be stated as follows:

Relativity is the result of difference in knowledge about Nature between observers who are at movement relative to each other.

Given the above definition, two questions arise: Why should any difference arise in knowledge between the two observers? And how would each observer know what knowledge the other observer acquires about some measurement? To answer these questions, we must define the way in which information about some physical measurement transfers from one observer to another. For rendering the proposed approach useful, I postulate that *information translated from one observer to another is carried by light or another information carrier of equal velocity*.

Under this specification, it becomes obvious that any information about time intervals, spatial distances, and so forth between observers who are at rest relative to each other will be kept unchanged. However, information translated between two observers who are in motion relative motion will suffer certain modulation. To summarize, the proposed Information Relativity theory (*IR*) rests on the two following axioms:

1. The laws of physics are the same in all inertial frames of reference (*SR*'s first axiom).

2. All translations of information from one frame of reference to another are carried by light or by another carrier with equal velocity (information-carrier axiom).

2. Information Relativity Time and Distance Transformations

In the present paper I focus only on the time and distance transformations. Derivations of the mass and energy densities transformations are detailed in "Information Relativity Theory (Part II) [12]. Moreover application of IR to cosmology is detailed in [13-15]. For the sake of completeness, the theory's main transformations are depicted in Table 1a in the Appendix.

2.1 Time

We consider the modulation of information regarding the time interval of a given event taking place in frame of reference F', while departing with constant velocity *v* with respect to an observer in another frame of reference *F*. Assume that at the "moving" frame F', a certain event started exactly at the time of departure (t=t'= 0). Assume that promptly at the termination of the event, the observer in the "moving" frame measures the time (denote it by t'), and with no delay, sends a wave signal to the observer in the "staying" frame in order to indicate the termination of the event. Also assume that with the arrival of the signal, the "staying" observer promptly registers his/her termination time, denoted by *t*. The termination time *t*, registered by the "staying" observer, is equal to *t'*, the termination time registered by the "moving" observer, plus the time the wave signal took to cross the distance *x* in *F* that the "moving" observer has crossed relative to the "staying" observer, from the moment the event started (*t*= 0) until it ended (t=*t*). The time in *F* that the wave signal took to cross the distance *x* is equal to $\frac{x}{c}$, where *c* is the velocity of the wave signal relative to the “staying” observer.

Thus, the termination time *t* registered by the "staying" observer is equal to:

$$t = t' + \frac{x}{c} \ . \qquad \text{.... (1)}$$

On the other hand, the distance *x* is equal to:

$x = v\,t\,.$ .... (2)

Substituting x from (2) in (1), we get

$$t = t' + \frac{vt}{c}\ , \qquad \text{.... (3)}$$

or

$$\left(\frac{t}{t'}\right)_{ER} = \frac{1}{1-\frac{v}{c}} = \frac{1}{1-\beta}\ , \qquad \text{.... (4)}$$

where $\beta = \frac{v}{c}$.

Notably, eq. (4) is fundamentally different from the famous time dilation prediction of SR $\left(\frac{t}{t'}\right)_{SR} = \gamma = 1/\sqrt{1-\beta^2}$. Figure 1 depicts the comparison between the two predictions.

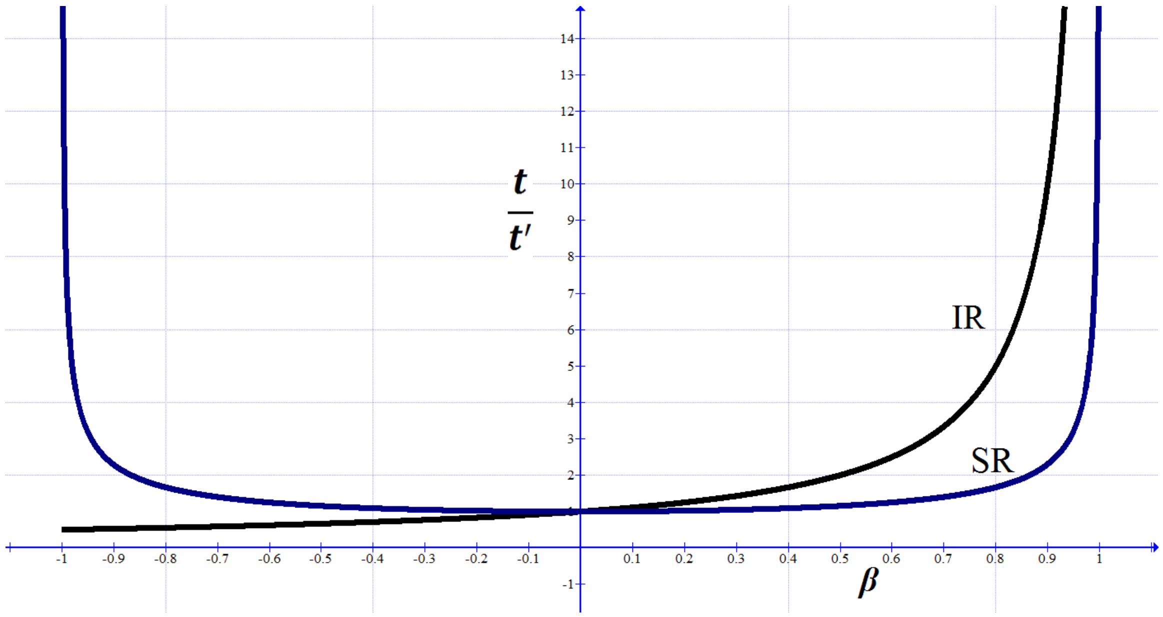

Figure 1: Time transformation in IR and SR

As the figure shows, for positive β values (F'departing from F), the predicted pattern of dependence of $\frac{t}{t'}$ on β is similar to the one predicted by SR, although the time dilation predicted by information modulation $\left(\frac{t}{t'}\right)_{ER}$ is larger than the time dilation predicted by SR.

Conversely, for negative β values (F' approaching F), the relative time $\frac{t}{t'}$ as a function of β depicts time contraction and not time dilation, as predicted by SR.

Note that equation (4) closely resembles the Doppler formula [16, 17]. The Doppler Formula predicts a red- or blueshift depending on whether the wave source is departing or approaching the observer. Similarly, Eq. (4) predicts that the time duration of an event on a moving frame is dilated or contracted depending on whether the frame is departing or approaching the observer.

2.2 Distance

Derivation of transformation of distance along the travel path, detailed in appendix A, yields the following equation:

$$\left(\frac{x}{x'}\right)_{IR} = \frac{(1+\beta)}{(1-\beta)}\,. \qquad \ldots\ldots (6)$$

The relative distance $\frac{x}{x'}$ as a function of β, together with the respective relative distance according to *SR* (in dashed black), are shown in Figure 2. Whereas *SR* prescribes that irrespective of direction, objects moving relative to an internal frame will contract, *IR* predicts that a moving object will contract or expand depending on whether it approaches the internal frame or departs from it.

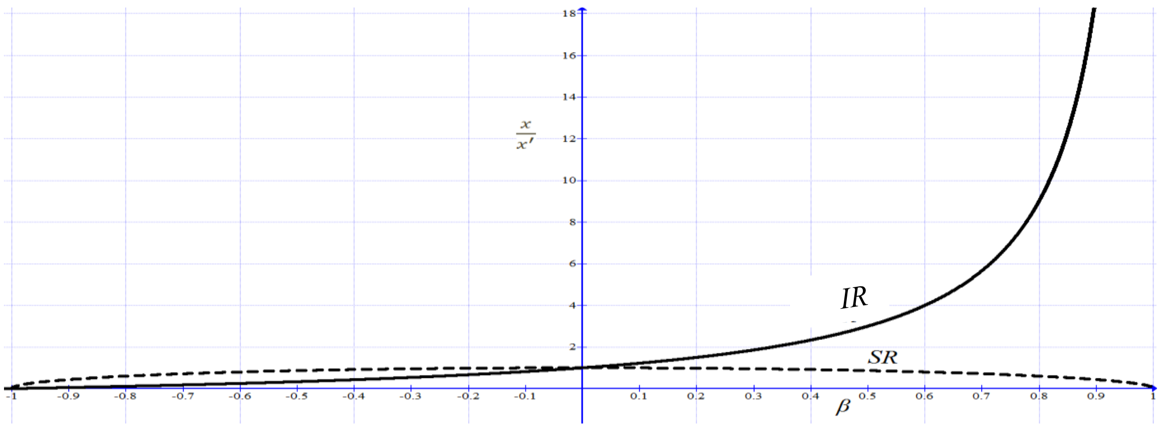

Figure 2: Distance transformation for the one-way trip. The dashed line depicts the corresponding prediction of SR.

3. Empirical validation of *IR*'s Time Transformation

I shall focus here on *IR*'s time transformation term, which is by far the most tested (and confirmed) prediction of *SR*. I shall demonstrate that *IR* performs as well as *SR* in predicting some important findings on which the empirical validity of *SR* is substantiated, including the results of several Michelson-Morley [18-24] type experiments and the time dilation in muon decay experiments (e.g., [25]) and the relativistic time gains reported in "around-the-world atomic clocks" experiments (e.g., [26]).

More importantly, I show that IR yields excellent predictions for two types of experiments which qualify as stringent falsification tests for LI and SR: The linear Sagnac effect [27, 28] and the neutrino velocity experiments conducted by OPERA and other collaborations [29-34]. I will show that for all the investigated experiments IR yields accurate predictions.

3.1 Prediction of Michelson-Morley's null result

In their seminal paper [18], Michelson and Morley (M&M) reported an experiment set to test the velocity of the motion of Earth in the presumed. M&M analyzed the motion of the parallel and perpendicular waves (with respect to Earth's motion). They found (incorrectly) that the displacement of the interference fringes is given by: $2\ D_0(\frac{v}{c})^2 = 2\ D_0\beta^2$, where D_0 is the interferometer arm's length at rest. It is well known that the results of the M&M experiment, and many subsequent experiments [e.g., 48-53], were far less than the above prediction. As M&M reported, "Considering the motion of the earth in its orbit only, this displacement should be $2\ D_0(\frac{v}{c})^2 = 2\ D_0 \text{ x } 10^{-8}$. The distance D was about 11 meters, or 2×10^7 wavelengths of yellow light; hence, the displacement to be expected was 0.4 fringes. The actual displacement was certainly less than the 20th part of this (prediction) and probably less than the 40th part," ([18], p. 341) which is "too small to be detected when masked by experimental errors" ([18], p. 337).

It is well-known that SR was successful in predicting the M&M null result without inclusion of the notion of ether, and that by this, it opened a new era of post-Newtonian physics. Here, I show that the proposed IR performs as well as SR in predicting the null effect. To account for the relativistic effects on the distance that light travels in the round trip, I replace $2D_0$ by $D_1 + D_2$ in the equation derived by M&M, where D_1 and D_2 are the departure and arrival distances, respectively. Using the distance transformation depicted in Table 1, we get:

Fringe Shift = $(D_1 + D_2)\,\beta^2 = D_0\left(\frac{1+\beta}{1-\beta} + \frac{1-\beta}{1+\beta}\right) = D_0 \frac{1+\beta^2}{1-\beta^2}\beta^2$ ….. (7)

Where $\beta = \frac{v}{c}$, c ≈ 299792.458 $km/_s$, and v is the velocity of Earth around the (v ≈ 29.78 $km/_s$). Substituting $\beta = \frac{29.78\ km/_s}{299792.458\ km/_s} \approx 9.9340 \times 10^{-5}$ and D_0 =11m (the interferometer's arm length in the M&M experiment) in eq. (7), we obtain a predicted fringe shift of approximately 1.09 x 10^{-7}, which is five orders of magnitude smaller than the reported experimental resolution (of ≤ 0.02). The comparable prediction made by SR is $2\,D\,\beta^2$ = $2\,D_0\,(\sqrt{1-\beta^2}\,\beta^2)$, which after substitution yields ≈ 1.97x 10^{-8}. Given the resolution in the M&M experiment, the difference between the two predictions (≈ 8.9 x 10^{-8}) is negligible. Table 1 summarizes similar calculations performed for several M&M type experiments, while contrasting them with the respective predictions of SR.

Table 1

Predictions of findings reported by classical Michelson-Morley type experiments

Experiment	**Arm length (meters)**	**Expected Fringe shift**	**Measured Fringe shift**	**Experimental Resolution**	**IR prediction**	**SR prediction**
Michelson and Morley [18]	11.0	0.4	< 0.02 or ≤ 0,01	0,01	≈ 4.34 x 10^{-7}	≈ 4.34 x 10^{-7}
Miller [19]	32.0	1.12	≤ 0.03	0.03	≈ 1.27 x 10^{-6}	≈ 1.26 x 10^{-6}
Tomaschek [20]	8.6	0.3	≤ 0.02	0.02	≈ 3.40 x 10^{-7}	≈ 3.40 x 10^{-7}
Illingworth [21]	2.0	0.07	≤ 0.0004	0.0004	≈ 7.89 x 10^{-8}	≈ 7.90 x 10^{-8}
Piccard & Stahel [22]	2.8	0.13	≤ 0.0003	0.0007	≈ 1.11 x 10^{-7}	≈1.11 x 10^{-7}
Michelson et al. [23]	25.9	0.9	≤ 0.01	0.01	≈ 1.02 x 10^{-6}	≈ 1.02 x 10^{-6}
Joos [24]	21.0	0.75	≤ 0.002	0.002	≈ 8.30 x 10^{-7}	≈ 8.30 x 10^{-7}

As the table shows, both theories predict the null results. Moreover, the differences between the predictions of IR and SR are either zero or in the order of magnitude of 10^{-10}.

3.2 Prediction of the time dilation of decaying muons

In muon-decay experiments, muons are generated when cosmic rays strike the upper levels of the Earth's atmosphere. They are unstable, with a life time of $\tau = 2.2\ \mu\ s$. With counters that count muons traveling within a velocity of 0.99450**c** to 0.9954**c**, comparing their flux density at both the top and bottom of a mountain gives the rate of their decay. In the most famous muon-decay experiment [25], assuming a velocity of 0.992c of muons in air, researchers found that the percentage of the surviving muons descending from the top of Mt. Washington to the sea level (d ≈ 1907 m.) was (72.2 ± 2.1) %, considerably higher than 36.79%, the expected percentage resulting from non-relativistic calculation.

To calculate the relativistic muon decay, denote the times at Earth and at a moun's frame by t and t', respectively. Without loss of generality, assume that at the mountain's level, t = t' = 0. For any time t' ($0 \leq t' \leq t'_B$), where t'_B is the muon's time arrival at the bottom, the flux density N(t') could be expressed as

$$\mathrm{N}(t') = \mathrm{N}(0)\ e^{-\frac{t'}{\tau}}, \qquad \text{..... (8)}$$

where N(0) is the count at the mountain's level. Substituting the value of t' from eq. (4), we get:

$$\mathrm{N}(t)_{CR} = \mathrm{N}(0)\, e^{-\frac{(1-\beta)t}{\tau}}. \qquad \text{..... (9)}$$

A similar analysis based on SR yields

$$\mathrm{N}(t)_{SR} = \mathrm{N}(0)\, e^{-\frac{\sqrt{1-\beta^2}\ t}{\tau}}. \qquad \text{..... (10)}$$

For β =0.992, Figure 3 depicts the rates of decay predicted by IR, SR, and a nonrelativistic calculation. For an ascending time of $\delta t = \frac{d}{v} = \frac{1907\ m.}{2.998\text{x } 10^8} \approx 6.36$ µs., the predictions of IR and SR are, respectively, $\frac{\mathrm{N}(t=6.36)_{CR}}{\mathrm{N}(0)}$ x 100= $e^{-\frac{(1-0.992)x\ 6.36}{2.2}}$ x 100 ≈ 97.7% and $\frac{\mathrm{N}(t=6.36)_{SR}}{\mathrm{N}(0)}$ x 100= $e^{-\frac{\sqrt{1-0.992^2}\ x\ 6.36}{2.2}}$ x 100 ≈ 69.42%. By contrast, according to nonrelativistic considerations, the expected percentage of surviving muons is only $\frac{\mathrm{N}(t=6.36)_{NR}}{\mathrm{N}(0)}$ x 100= $e^{-\frac{6.36}{2.2}}$ x 100 ≈ 5.55%. Comparison with the observed percentage of 72.2% strongly indicates that a classical analysis fails to account for the observed phenomenon, whereas the two relativistic approaches succeed in achieving that. Note that the predicted values of both theories are not precise, given the fact that the theoretical calculations ignore several factors affecting the flight of descending particles [35].

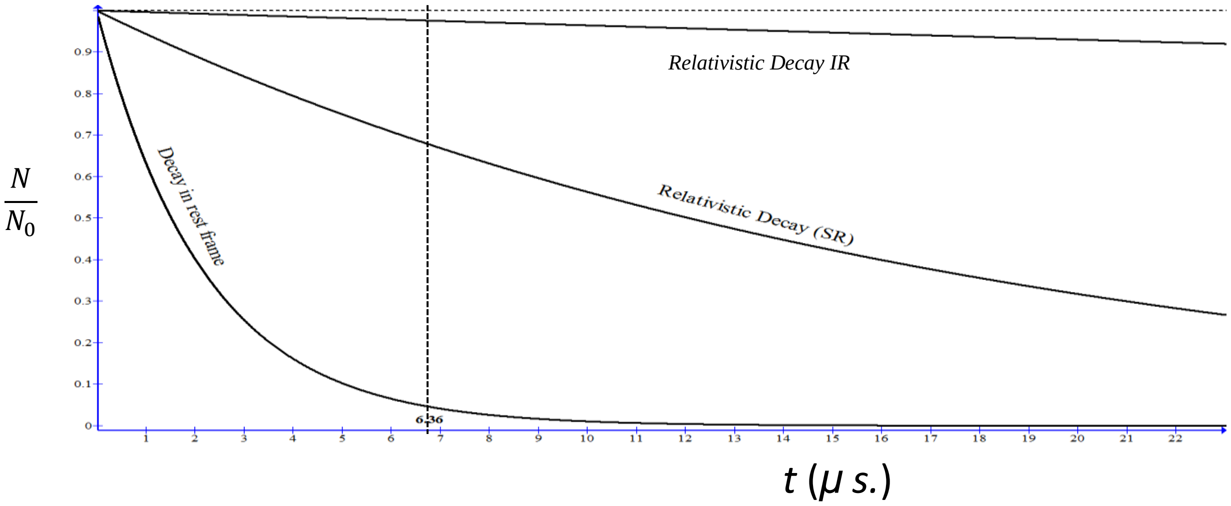

Figure 3: Predicted rates of muon decay

3.3 **Around the World Atomic Clocks experiments**

Around the world type of experiments represent a direct way to test the time dilation prediction using highly accurate atomic carried by aircrafts flying eastward or westward around the world (see e.g., [26]). Given the relatively low velocity of airliners compared with the velocity of light, such experiments, in similarity to the M&M experiments are incapable of discriminating between SR and IR, since, as will be shown hereafter, both theories yield almost identical predictions.

For an "around the world trip", SR's time dilation is given by:

$$\tau_{SR} = \frac{t}{t'} = \frac{2}{\sqrt{1-\beta^2}}, \qquad \beta = \frac{v}{c} \qquad \text{..... (11)}$$

While IR's prediction is:

$$\tau_{IR} = \frac{t}{t'} = \left(\frac{1}{1-\beta} + \frac{1}{1+\beta}\right) = \frac{2}{1-\beta^2} \qquad \text{..... (12)}$$

Figure 4 depicts the predictions of SR and IR for relatively low velocities.

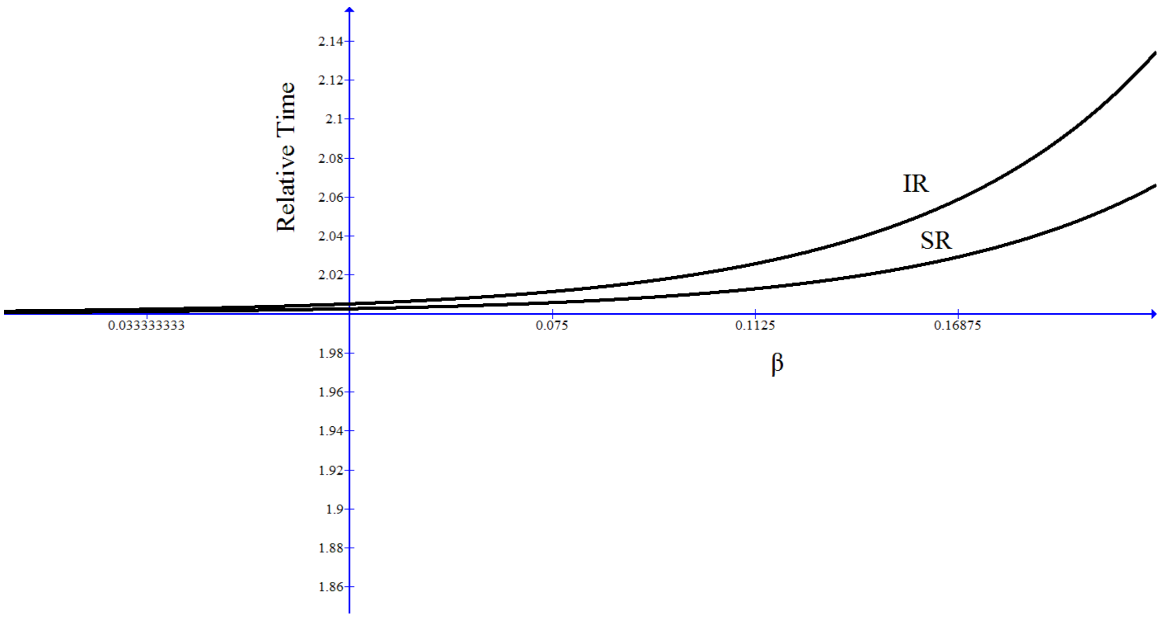

Figure 4: predictions of SR and IR for relatively low velocities

For a cruising air speed for long-distance commercial passenger flights, the estimated velocity is 475–500 knots (878-926 km/h). The resulting difference in relative time between IR and SR predictions for this speed range is ≈0.0007, which requires for its detection a measurement sensitivity of at least 4 degrees of magnitude more than the sensitivity of measurements reported in [26].

3.4 Linear Sagnac Effect

First, a brief introduction: The Sagnac effect, named after its discoverer in 1913 [36], has been replicated in many experiments (for reviews, see [37-41]). The Sagnac effect has well-known and crucial applications in navigation [38] and in fiber-optic gyroscopes (FOGs) [42-46]. In the Sagnac effect, two light beams, sent clockwise and counterclockwise around a closed path on a rotating disk, take different time intervals to travel the path. For a circular path of radius R, the time difference can be represented as $\Delta t = \frac{2\,v\,l}{c^2}$, where $v=\omega\, R$ and l is the circumference of the circle ($l=2\pi R$). Today, FOGs have become highly sensitive detectors measuring rotational motion in navigation. In the GPS system, the speed of light relative to a rotating frame is corrected by $\pm\, \omega\, R$, where ω is the radial velocity of the rotating frame and R is the rotation radius. A plus/minus signs is used depending on whether the rotating frame is approaching the light source or departing from it, respectively.

Many physicists claim that because the Sagnac effect involved a radial motion, it does not contradict SR and that it should be treated in the framework of general relativity [47, 48]. However, Wang at al. [27, 28] strongly refute this claim in two well-designed experiments that show unambiguously that an identical Sagnac effect appearing in uniform radial motion occurs in linear inertial motion. For example, Wang et al. [27] tested the travel-time difference between two counter-propagating light beams in uniformly moving fiber. Contrary to the LI principle and to the prediction of SR, their findings revealed a travel-time difference of $\frac{2v\,\Delta l}{c^2}$, where Δl is the length of the fiber segment moving with the source and detector at a v, whether the segment was moving uniformly or circularly. This finding in itself should have raised serious questions about the validity of the LI principle and SR. If the Sagnac effect can be produced in linear uniform motion, then the claim that it is a characteristic of radial motion is simply incorrect. Because the rules SR apply to linear uniform motion, the only conclusion is that SR is incorrect. Strikingly, the unrefuted detection of a linear Sagnac effect and its diametrical contradiction with SR has hardly been debated.

Applying IR to the linear Sagnac experiment yields the following difference between the arrival times of the two light beams:

$$\Delta t = \frac{\Delta l}{c-v} - \frac{\Delta l}{c+v} = \frac{2v\,\Delta l}{(c-v)(c+v)} = \frac{2v\,\Delta l}{c^2 - v^2} \approx \frac{2v\,\Delta l}{c^2}\ , \qquad \ldots (13)$$

which is in agreement with the analysis and results reported in [27].

3.5 Predictions of neutrino velocities

First, a brief introduction: In 2011, the OPERA collaboration at CERN announced that neutrinos had travelled faster than light [49]. The reported anticipation time was 60.7 ±6.9 (stat.)± 7.4 (sys.) ns, and the relative neutrino velocity was $\frac{v-c}{c}$ = (5.1 ±2.9) ×10^{-5}. The excitement that swept physicists and laymen concerning the possibility that a new era was "knocking on physics doors" waned a few months later, after OPERA reported the discovery of hardware malfunctions in the GPS system, which resulted in a critical measurement error. After accounting for the error, the anticipation time was only $(2.7 \pm 3.1\ (\text{stat.}) + {}^{+3.8}_{-2.8}$ (sys.)) ×10^{-6}, with corresponding $\frac{v-c}{c}$ = 2.67 x 10^{-6} [29]. Since then, the OPERA and several collaborations, including ICARUS, LVD, and Borexino, have replicated the “null” result [30-33]. The only "faster-than-light" result of which I am aware was reported in 2007 by the MINOS collaboration [34], who reported an early anticipation time of 126 ± 32 (stat.) ± 64 (sys.) ns (C.L. = 68%), with corresponding $\frac{v-c}{c}$ = 5.1±2.9 (stat.+sys.)×10^{-5}. However, the high statistical and system errors reported by MINOS impede the validity of the above quoted result.

Surprisingly, despite the vast body of theoretical research on the topic [e.g., 50-57], no one has attempted to apply SR to deriving point predictions of the $\frac{v-c}{c}$ results reported by OPERA and other collaborations that replicated the "null" result. I will demonstrate that IR precisely predicts six experimental results reported by OPERA, MINOS, ICARUS, LVD, and Borexino collaborations (see Table 2). Given the stark contradiction between the time transformations of IR and SR, one must expect that any attempt to test SR's predictions for the above-mentioned experiments will fail colossally.

To derive the term $\frac{v-c}{c}$ for a typical neutrino-velocity experiment, consider a neutrino that travels a distance *d* from a source (e.g., at CERN) and arrives at a detector (e.g., at Gran Sasso). According to IR, such an experiment includes *three* frames: the neutrino frame *F*, the source frame F', and the detector frame F''. *F* is departing from F' with velocity *v* and approaching F'' with velocity – *v*. F' and F'' are at rest relative to each other. Using eq. (4), we can write

$$\Delta t_S = \frac{\Delta t}{1-\frac{v}{c}}, \qquad \text{……} (14)$$

and

$$\Delta t_D = \frac{\Delta t}{1-\frac{-v}{c}} = \frac{\Delta t}{1+\frac{v}{c}} \qquad \text{……} (15)$$

Where *v* is the neutrino velocity, *c* is the velocity of light. Δt, Δt_S, and Δt_D are the times, as measured in frames *F* (neutrino rest-frame), F' (source), and F'' (detector), respectively.

The neutrino time of flight tof_v is equal to difference between the times as measured in the detector and the source, or:

$$tof_v = \frac{d}{v} = \frac{\Delta t}{1+\frac{v}{c}} - \frac{\Delta t}{1-\frac{v}{c}} = - \frac{2\,\frac{v}{c}}{1-(\frac{v}{c})^2}. \qquad \text{….} (16)$$

Where d is the travel distance. For an *early* neutrino arrival time, δt, with respect to the velocity of light, we can write:

$$\frac{d}{c} - \delta t = tof_v = - \frac{2\frac{v}{c}}{1-(\frac{v}{c})^2} \frac{d}{v} . \qquad \text{….. (17)}$$

Solving for $\frac{v}{c}$ yields

$$\frac{v}{\mathrm{c}} = (\frac{2}{1-\frac{\mathrm{c}\,\delta t}{d}} - 1)^{\frac{1}{2}}, \qquad \text{…. (18)}$$

Or:

$$\frac{v-\mathrm{c}}{c} = \sqrt[2]{\frac{2}{1-\frac{\mathrm{c}\ \delta t}{d}} - 1} - 1 . \qquad \text{…. (19)}$$

To demonstrate, for the OPERA-corrected result [29], d = 730.085 km and δt = (6.5 ± 7.4 (stat.) $\pm {}^{+9.2}_{-6.8}$ $(sys.)$) ns. Substituting in eq. (19), we get:

$$\frac{v-\mathrm{c}}{\mathrm{c}} = (\frac{2}{1-\frac{299792.458\ x\ 6.5\ x\ 10^{-9}}{730.085}} - 1)^{\frac{1}{2}} - 1 \approx - 2.67 \text{ x } 10^{-6} \qquad \text{…. (20)}$$

Which is almost identical to the reported result of $\frac{v-\mathrm{c}}{\mathrm{c}}$ $(Exp.)$ = (2.7 ± 3.1 $(stat.)$ $\pm{}^{+3.8}_{-2.8}$ (sys.))$\times 10^{-6}$. Applying eq. (19) to five others experiments, conducted by MINOS, OPERA, ICARUS, LVD, and Borixeno collaborations, yields the results summarized in Table 2. As the table shows, the mode yields precise predictions for all the tested experiments.

Table 2

Predictions of ER for six neutrino-velocity experiments

Experiment	**Experimental** $\frac{v-\mathrm{c}}{\mathrm{c}}$	**Predicted** $\frac{v-\mathrm{c}}{\mathrm{c}}$
OPERA 2012 (corrected result) [29]	**(2.7 ± 3.1 $(\mathbf{stat.})$ + ${}^{+3.8}_{-2.8}$ (sys.)) ×10^{-6}**	**2.67 x 10^{-6}**
OPERA 2013 [30]	**(- 0.7 ± 0.5 $(\mathbf{stat.})$ +${}^{+2.5}_{-1.5}$ (sys.)) ×10^{-6}**	**- 0.66 x 10^{-6}**
ICARUS 2012 [31]	**(0.4 ± 2.8(stat.) ± 9.8 (sys.)) ×10^{-7}**	**0.41 x 10^{-7}**
LVD [32]	**(1.2 ± 2.5(stat.) ± 13.2 (sys.)) ×10^{-7}**	**1.23 x 10^{-7}**
Borexino [33]	**(3.3 ± 2.9(stat.) ± 11.9 (sys.)) ×10^{-7}**	**3.28 x 10^{-7}**
MINOS 2007 [34]	**(5.1±2.9))(stat) ×10^{-5}**	**5.14 10^{-5}**

4. Summary and Concluding Remarks

Einstein's relativity theory dictates, as a *force majeure*, an ontic view of the world, according to which relativity is a true state of nature. Here, I took a fundamentally different approach that adopts an epistemic view, according to which relativity results from a difference in information (knowledge) about Nature between observers who are in relative motion with respect to each other. Postulation that the laws of physics are the same in all inertial frames of reference (SR's first axiom), and specifying that information translated from one frame of reference to another is carried by light or another information carrier of equal velocity, I calculated the modulations in information about measurements of time and distance.

IR has some nice properties: (1) it is very simple. (2) It satisfies the EPR necessary condition for theories *completeness*, in the sense that "every element of the physical reality must have a counter part in the physical theory" (see [9], p. 777). In fact, all the variables in the theory are observable by human senses or are directly measurable by human-made devices. (3) The theory applies, without alterations or the addition of free parameters, to describing the dynamics of very small and very large bodies.

Applying the theory's time transformation to the twin paradox, detailed in [58] yields a commonsense solution, according to which the twins reunite after aging equally. This solution does not require an arbitrary designation of Earth as the “preferred” frame of reference, which stands in opposition to the mere idea of relativity. For the domain of small particle physics, I have shown here that IR succeeds like SR in explaining the "null" result of the famous Michelson-Morley experiment, the time dilation of decaying muons, and the time gain reported in around-the-world clocks experiments. More important, IR accounts for the well-known Sagnac Effect and for the results of six recent neutrino-velocity experiments, conducted by OPERA, MINOS, ICARUS, LVD, and Borixeno, whereas SR fails to do so.

Of note is that analysis of the mass-energy transformations, detailed in part II of this article [12], reveals a highly intriguing connectedness, of Golden Ration [59, 60] symmetry, between relativity and quantum mechanics, while suggesting a plausible relativistic explanation of mass-wave duality, and of quantum criticality and entanglement. Moreover, application of the transformations derived here to cosmology and astrophysics, in complementarity with the classical Doppler effect, proves impressively successful in suggesting plausible answers to key cosmological questions, including the inflationary expansion of the universe at very high redshifts [13], the nature of dark matter and dark energy [13, 14], the evolutionary timeline of chemical elements, the nucleosynthesis [13], and the dynamics of massive black holes at the center of galaxies [15]. Moreover, the derived expressions for (Ω_{matter},Ω_{Λ}) fit nicely with the findings of several observations based on ΛCDM cosmologies, conducted at various redshift ranges [13].

It is important to stress that both the linear Sagnac effect and the neutrino-velocity experiments (although the second was not intended to do so) constitute stringent tests for the LI principle, and thus qualify for pitting IR against SR, such that if one is confirmed the second is automatically refuted. This is because the two experimental designs include both departure *and* arrival of moving bodies, from/towards frames of reference. In the Sagnac design, the moving fiber detector travels once in the same direction of the light travel, and once in an opposite direction to the light's travel direction. In the neutrino experiments the neutrino beams travel away from their source, while simultaneously approaching the detector. Based on the analyses detailed in the present paper, it is fair to say that taken together, IR performs better than SR, and most importantly it performs outstandingly well where LI breaks down completely and with it SR.

A faulty argument, often raised by proponents of SR, is that the theory has been repeatedly confirmed by hundreds of different experiments. This argument is simply nonscientific, since it defies the essence of scientific inquiry, postulated in Carl Popper's falsification principle [61, 62]. In fact, Albert Einstein himself, in reflecting about this cardinal principle, pointed out that, “If an experiment agrees with a theory, it means ‘perhaps’ for the latter; if it does not agree, it means ‘no’” (quoted in ref. 62, p. 203). It is argued here that despite thousands of LI "spontaneous" breaking at high enough energies, not even one experiment was premeditatedly designed to seriously challenge LI and SR. A necessary and sufficient condition for such falsification test is that it should enable separate measurements of a particle's time travel t_1, as it *flies away* with velocity v from an observer's frame of reference F_1 , say from distance *x*=0 *to distance x*=*L*, *and* the time travel t_2 of an identical particle as it *flies towards* an observer's frame of reference F_2, with equal velocity and from equal distance (in F_1). Simple calculation (see appendix B) shows that under SR, the time ratio δ defined as $\delta = \frac{t_1 - t_2}{t_1 + t_2}$, should equal zero, independently of the particle's velocity, while under IR δ is predicted to be linearly increasing with the particle's velocity.

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Appendix A

Distance transformation

Consider the two frames of reference F and F'shown in Figure 3. Assume the two frames are moving away from each other at a constant velocity *v*. Assume further that at time t_1 in F (and t_1' in F'), a body starts moving in the +*x* direction from point x_1 (x_1' in F') to point x_2 (x_2' in F'), and that its arrival is signaled by a light pulse that emits exactly when the body arrives at its destination. Denote the internal framework of the emitted light by F_0. Without loss of generality, assume $t_1 = t_1' = 0$, $x_1 = x_1' = 0$. Also denote t_2 = , $t_2' = t'$, $x_2 = x$, $x_2' = x'$.

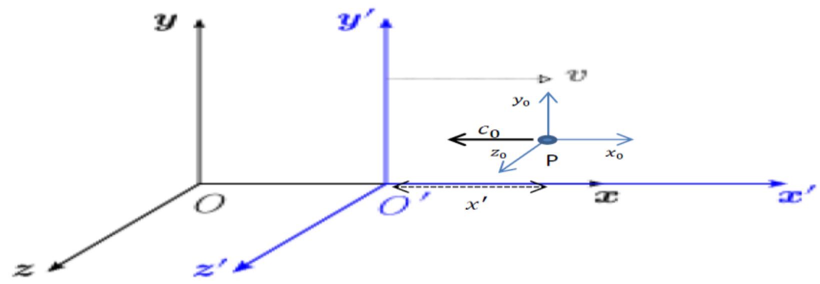

Figure 1a: Two observers in two reference frames, moving with velocity v with respect to each other

From eq. (4), the time t_p in F_0 that the light photon takes to reach an observer in F' equals

$$t_p = (1 - \left(-\frac{v}{c}\right)\ )\, t' = (1 + \beta)\, t', \qquad \text{..... (1a)}$$

where t' is the corresponding time in F' and c is the velocity of light in the internal frame. Because F' is moving away from F with velocity v, the corresponding time that the light photon takes to reach F is equal to

$$t = t_p + \frac{vt}{c} = t_p + \beta\, t. \qquad \text{...... (2a)}$$

Substituting t_p from eq. (1a) in eq. (2a) yields

$$t = (1 + \beta)\, t' + \beta\, t\,,$$

or

$$\frac{t}{t\prime} = \frac{(1+\beta)}{(1-\beta)}\ . \qquad \text{...... (3a)}$$

But $x = c\,t$ and $x' = $ c t'. Thus, we can write:

$$\frac{x}{x\prime} = \frac{(1+\beta)}{(1-\beta)} \qquad \text{....... (4a)}$$

Appendix B

Consider a particle traveling at constant velocity v in the $+x$ direction. Denote by t_1 the particle's time travel, as it travels a distance L away at velocity v from an observer in frame of reference F_1. *Similarly,* denote by t_2 an identical particle's time travel, as it travels the same distance with the same velocity towards an observer in another frame of reference F_2.

Denote the particle's time at its rest frame by t_0.

SR's Predictions are: $t_1 = t_2 = \gamma\, t_0$ …… (1b)

While IR's Predictions are: $t_1 = \frac{1}{1-\beta}\, t_0$, $t_2 = \frac{1}{1+\beta} t_0$ …… (2b)

Define: $\delta = \frac{t_1 - t_2}{t_1 + t_2}$. According to *SR* we can write:

$$\delta_{SR} = \frac{t_1 - t_2}{t_1 + t_2} = \frac{\gamma\, t_0 - \gamma\, t_0}{2\gamma\, t_0} = 0, \qquad \text{…… (3b)}$$

Whereas, according to *IR* we have:

$$\delta_{IR} = \frac{\left(\frac{1}{1-\beta} - \frac{1}{1+\beta}\right) t_0}{\left(\frac{1}{1-\beta} + \frac{1}{1+\beta}\right) t_0} = \frac{\frac{(1+\beta)-(1-\beta)}{1-\beta^2}}{\frac{(1+\beta)+(1-\beta)}{1-\beta^2}} = \frac{2\beta}{2} = \beta \qquad \text{…… (4b)}$$

The difference between the two predictions is stark. *SR* predicts that the times ratio δ will be zero, independently of the particle's velocity, while *IR* predicts a linearly increasing function of δ in its dependence on velocity.